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Microscale Metallography Using Focused Ion Beam

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Microstructural examination can provide a rich tapestry of information about the processing and application history of a metal component. For this reason, microstructural characterization is a fundamental tool for failure analysis of these components. To reduce costs and accommodate demands for smaller packaging, many applications currently use metallic components where the critical dimensions are only a few micrometers. In these instances, traditional metallographic techniques, including polishing and etching, are ineffective for microstructural characterization because small grain sizes make etching impossible or damage induced by mechanical grinding masks features of interest. An alternative technique is therefore needed to perform microscale metallography.

Focused ion beam (FIB) is an ubiquitous instrument used for preparing transmission electron microscopy (TEM) samples and is being increasingly used to cross section small components and thin material layers on circuit boards. These applications leverage the ability of the FIB to make precise "cuts" without causing significant damage to the region of interest. In this way, the FIB cannot only alleviate or even eliminate the need to mechanically prepare a sample, but can also isolate specific locations for analysis. More importantly, however, the ion-sample interaction provides a unique way of viewing and probing the microstructure. Figure 1 provides a comparison of a gold plating (with nickel underlayer) cross-section imaged and prepared by FIB to that of a similar region of the same sample imaged by scanning electron microscopy (SEM) after standard metallographic preparation.

Imaging contrast in a FIB is caused by a similar phenomenon as backscatter electrons in SEM. Instead of atomic number dictating backscattering however, ions are reflected or absorbed to differing degrees depending on the crystallographic orientation of the grains. If a grain is oriented such that incident ions can channel along a crystallographic direction with minimal atomic interaction then the region appears dark. Alternatively, bright regions are those where ions are effectively backscattered to the detector. In this manner, not only are grains very visible, but contrast can also be manipulated by changing the orientation of the sample surface to the incident beam.

We have used FIB to obtain valuable information that helped us resolve many failure analysis projects. In one example, we examined the microstructure of poorly performing metal plating that was less than 2 μm thick. By noting whether the microstructure was columnar or equiaxed as well as the quantity of porosity present, we were able to draw conclusions linking performance to the quality control of the plating chemistry and process. In another example, we used FIB to view the integrity of an intermetallic compound in wire bonds on frequently failing computer processors, highlighting specifically, the porosity that can easily be disguised by smearing during mechanical metallographic preparation.

In this talk, I will review the technique of using FIB for microscale microstructural characterization. To this end, I will briefly introduce FIB instrumentation and ion-sample interaction before discussing its benefits and shortcomings with respect to this application. I will conclude by providing examples and citing case studies where this technique has augmented root cause failure analysis.

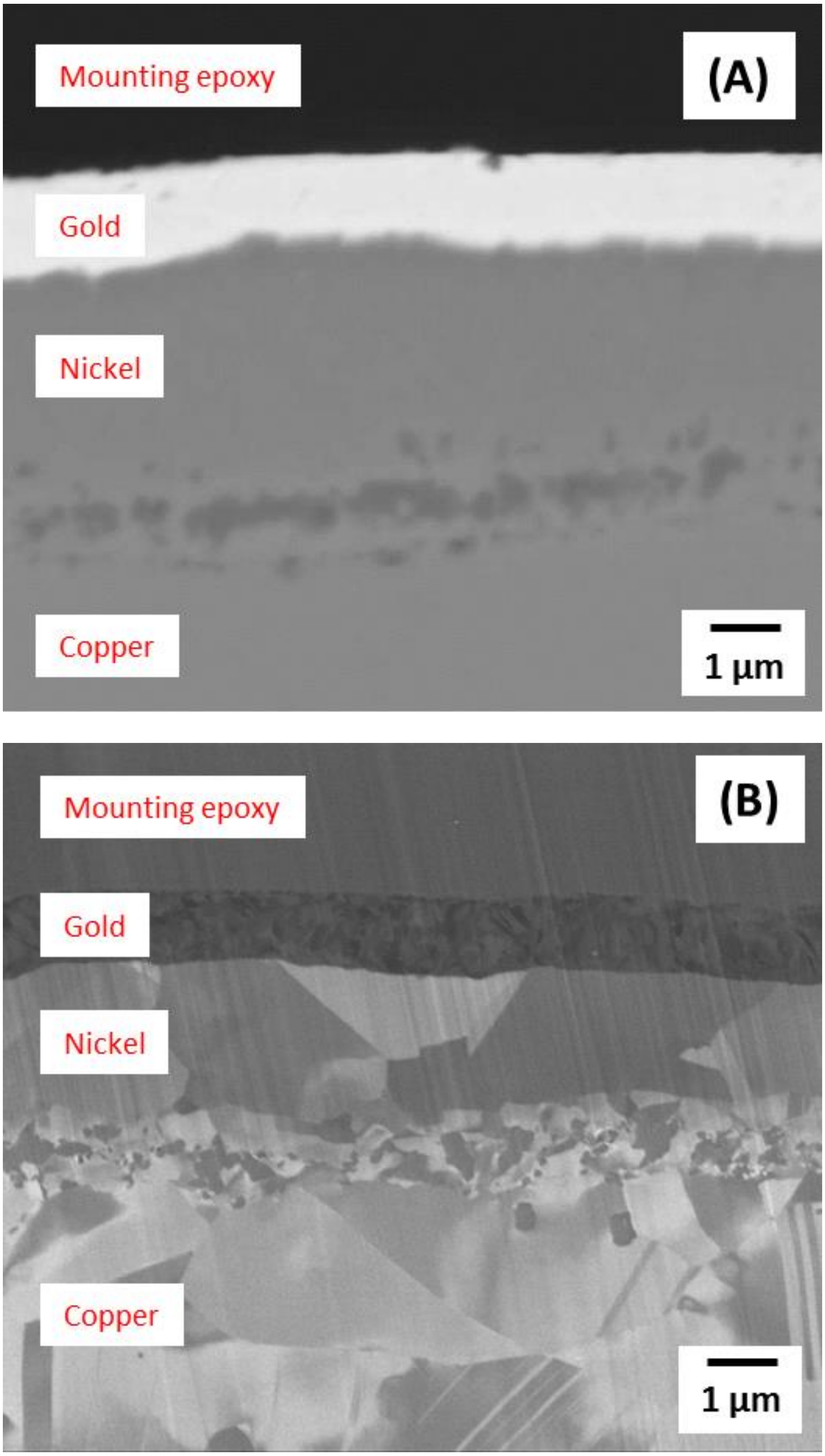

Figure 1. A comparison of the microstructures of a gold plating, nickel underlayer, and copper substrate imaged using (A) scanning electron microscopy after standard metallographic preparation and (B) focused ion beam.

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